ENVIRONMENTAL, SAFETY & HEALTH MANAGEMENT DURING CONSTRUCTION OF PILED ROAD STRUCTURES ON EXISTING LANDFILL SITE

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ABSTRACT

Optimizing land use has always been a constant challenge in urbanized and land scarce Singapore. To meet the demand of rapidly increasing road users and to provide vital links to developing areas in the north eastern part of Singapore, a new road was built at an existing landfill site, the Tampines Dumping Ground which was used for disposal of municipal waste and construction debris between 1983 and 1989. At the commencement of road work in 2006, it was found that the waste below the proposed road was still in active state of decomposition and various by-products like landfill gases and leachate were detected within and adjacent to the landfill boundary. This article highlights the risk management approach in planning, developing and implementing an environmental, health and safety management system to ensure safe construction and operation of the piled road structure at the landfill site.

1. INTRODUCTION

A 1.3km long dual 3-lane arterial road connecting Buangkok Drive to Tampines Road was built in 2009 as part of the road development plan to expand the road network at the north eastern part of Singapore (Figure 1). The S$33.9 milllion new road comprises a 3-span bridge across Sungei Serangoon river, 0.7km long piled roadway on landfill, a flyover over Kallang Payar Lebar Expressway (KPE) and connecting slip ramps. It provides a direct link between the residential towns at Ponggol and Sengkang to KPE and effectively shortens the travel time and benefits residents travelling to the central business district in the city.

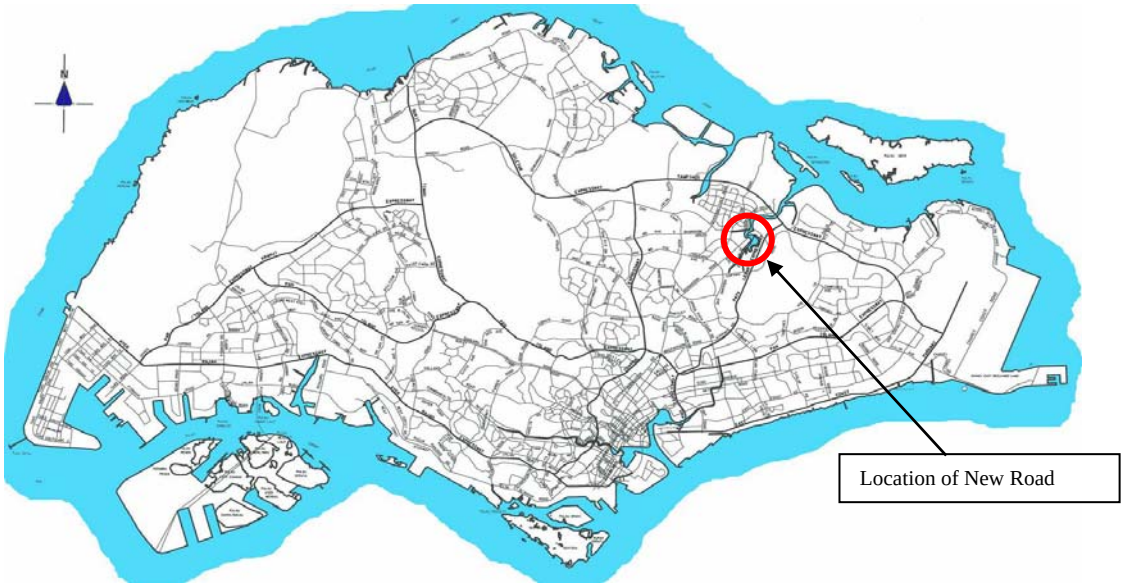

Figure 1: Location of new road at north eastern part of Singapore

Construction of the new road started in 2006. The main challenge encountered was roadwork at the landfill site, which was previously a dumping site for municipal waste and construction debris between 1983 and 1989 (Figure 2). Waste deposition had ceased and the dumping site which was managed by the National Environment Agency (NEA) was undergoing rehabilitation before roadwork commenced.

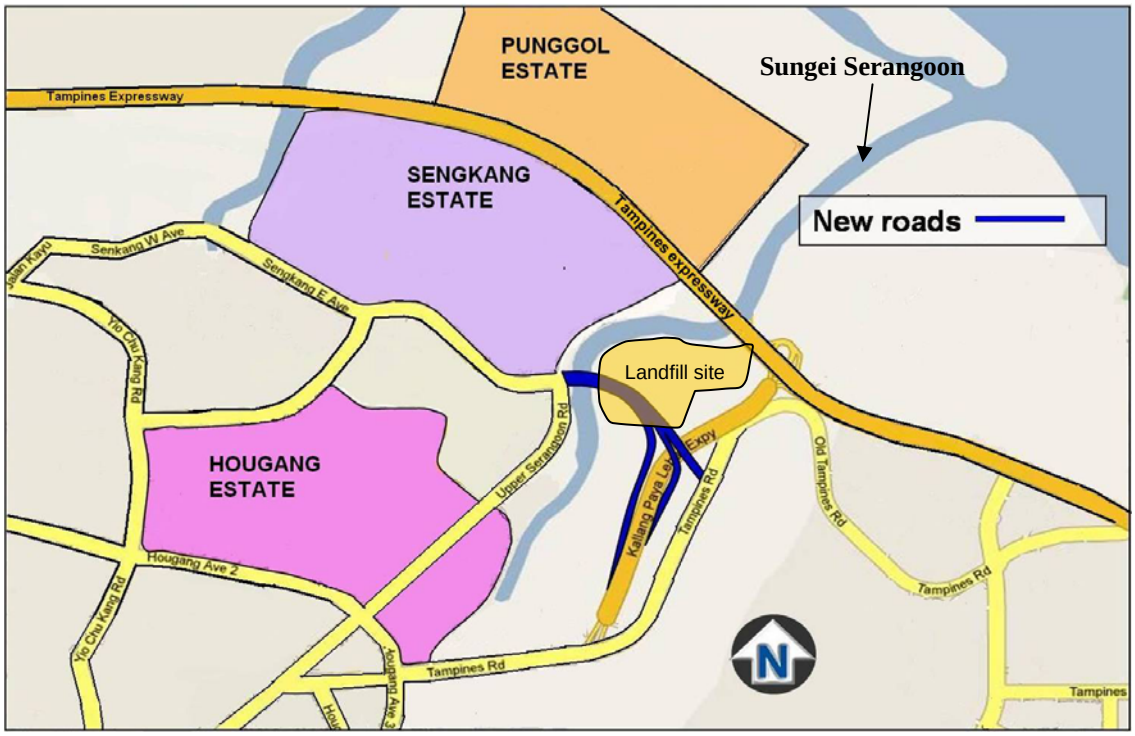

Figure 2. New road built on part of the existing landfill site

This article highlights the risk management approach in planning, developing and implementing an environmental, health and safety management system to ensure safe construction and operation of the piled road structure at landfill site. The process was undertaken and reviewed throughout the project from design to construction and handing over stages. It involved advance investigation of the landfill site to establish the environmental baseline and to determine potential hazards, development of

an environmental, health and safety management system to mitigate associated risks, implementing the mitigation measures and review of the system to avoid injuries and ill health arising from the construction, monitoring and maintenance of works in and adjacent to the landfill area.

2. ESTABLISHING AN ENVIRONMENTAL BASELINE AT LANDFILL SITE

The first phase of risk management process for construction of new road at landfill site involved the establishment of an environmental baseline for landfill related hazards. The objective was to identify all potential hazards which included:

- **Landfill Gas (LFG).** LFG is a by-product of waste decomposition and comprises mostly methane, carbon dioxide and trace amounts of volatile and odorous gases like hydrogen sulphide, volatile organics. Methane is of concern as it is toxic, flammable and explosive when its concentration in air is between 5% to 15% by volume or when it is in a confined or semi-confined space and when a source of ignition is present.

- **Leachate.** Leachate is another by-product of waste decomposition. As leachate can have a chemical and biological oxygen demand several times higher than untreated sewage effluent, its environmental impact can be considerable. In addition, leachate may contain heavy metals, ammonia, chloride, iron and trace organic compounds which are hazardous to wildlife and human health.
- **Geotechnical stability.** As the waste decomposes, there is a loss of volume resulting in gravitational settlement and compaction over time. This poses a threat to any structures on the waste deposit including placement of civil engineering works on site.

An environmental baseline study at the landfill site was carried out prior to the design and construction. Apart from making reference to available environmental data for the landfill area from NEA, additional site investigation from trial pit excavation, boreholes and monitoring wells were conducted along the entire stretch of road. Environmental baseline data collected over a period of 6 months included landfill gas concentration, flowrate, migration, leachate characteristics, soil log and extent of waste deposits, type and age of waste deposited, ground water levels and flow direction.

The results of the environmental baseline study revealed that the waste deposit occurred extensively at 4 to 10 metres below the proposed road level and its thickness varied from 2 to 10 metres. This mapping of landfill site enabled the designer to determine suitable type of foundation to support the road. A piled road structure was therefore adopted to avoid future road settlement due to geotechnical instability arising from waste decomposition. In addition, bored piles were designed to be installed through the waste deposit layer to the firm stratum below and they were protected against leachate corrosion by using HDPE pipe sleeves (Figure 3).

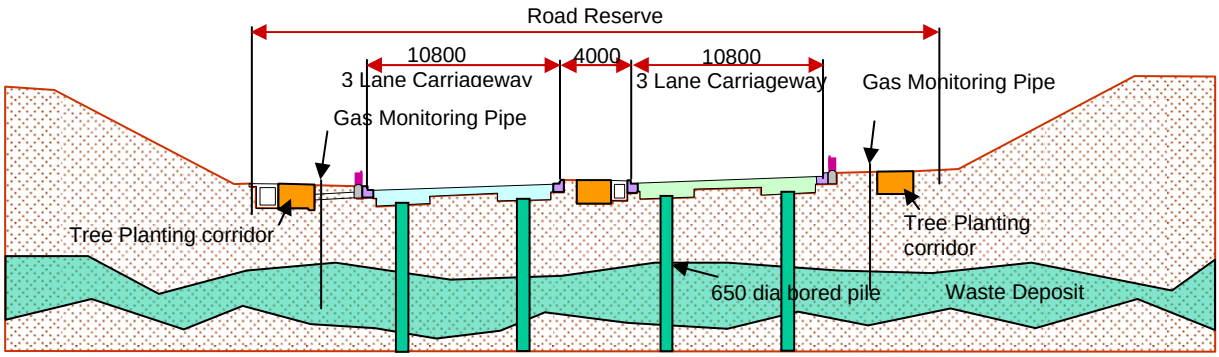

Figure 3: Typical Cross Section of Piled Road Structures

For the landfill gas measurement along the road, the environmental baseline study showed that peak methane gas concentration recorded were higher than expected – ranging from 45% to maximum of

81% in several boreholes. This was an indication of active methane generation from the waste decomposition.

On the other hand, leachate quality was unremarkable, with low to moderate levels of biological and chemical oxygen demand and a near neutral pH. This suggested that leachate generation had abated.

Based on these environmental baseline data, a landfill capping and gas control system was designed to provide a separation barrier to prevent contamination with leachate and to provide a safe means for venting gas from under the proposed road (Figure 4).

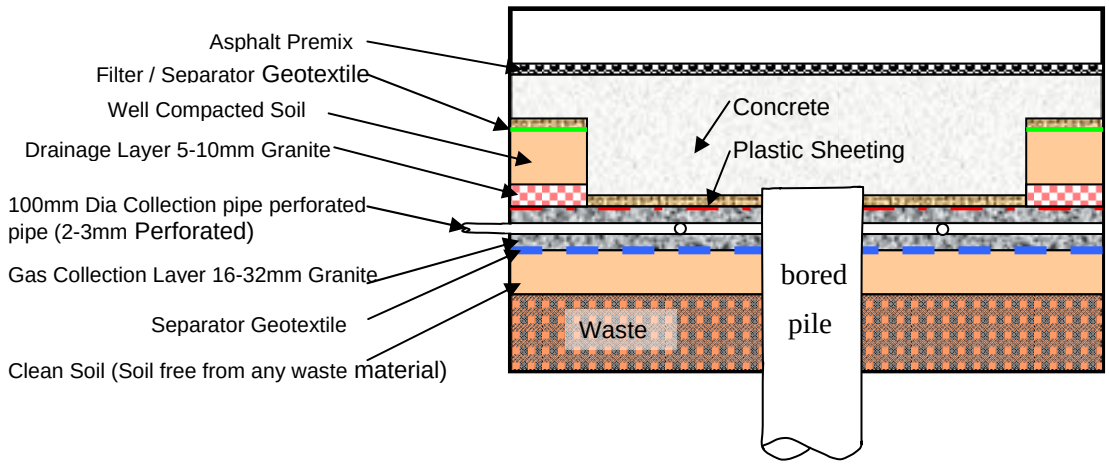

Figure 4: Cross section of road showing landfill capping and gas venting system

Considering the design, construction and maintenance of road structure including landfill capping and gas venting system in relation to the environmental hazards identified, it was assessed that landfill gas posed the most significant risk with regard to health and safety of work personnel.

3. DEVELOPING AN ENVIRONMENTAL HEALTH AND SAFETY MANAGEMENT SYSTEM

With the establishment of environmental baseline for landfill related hazards, a risk analysis workshop was concurrently held among the designer, contractor and owner representatives. The team systematically examined all hazards, their probability of occurrence and severity of impacts during construction, maintenance and operation stages. The resulting risk register with mitigation measures was formalised as a key document to be reviewed regularly by the project management team.

It was also determined that proactive planning, implementation and control of mitigation, precautionary measures were imperative to prevent health and safety risks to site personnel associated with construction and maintenance of the road.

An environmental health and safety management system (**EHS**) was therefore developed to guide the contractor and supervision team in managing the risks during construction, monitoring and maintenance of the road. The key requirements of the system included:

- **Defining safety organization and designation of safety responsibilities to site personnel**

  A team of safety personnel led by a senior safety officer was tasked to:

  i) conduct daily monitoring and data recording pertaining to LFG and other hazards including leachate and geotechnical stability;
  ii) report data to site management and regulatory authorities;
  iii) implement suitable training programs for site personnel;
  iv) brief visitors on safety protocol and hazards on site;

v) ensure that site personnel were appropriately briefed and received appropriate training on site hazards;
vi) develop and maintain a suitable emergency procedure in the event of gas detection;
vii) develop and enforce excavation procedure; and
viii) develop and enforce permit-to-work system

- **Implementing safety management procedures**

  Safety procedures were developed to minimise risks of fire, explosion, asphyxiation of workers and toxicity effects during trenching, excavation and creation of confined spaces at, near or below ground level. In addition, gas detection equipment and appropriate breathing apparatus were provided to site personnel. Monitoring frequency and measurement method were also specified. Procedure for dumping of excavated waste and control of leachate were developed.

- **Ensuring safe working environment, adopting appropriate emergency procedures and dissemination of safety information to site personnel**

  General safety and health control measures including warning signs, permit to work for hot work, removal of ignition source, providing fire extinguishing equipment, first aid facilities, restricting speed limit of construction vehicle, control of entry to confined space, actions to be taken in event of gas being detected in excavation etc. were developed.

- **Providing suitable health and safety training to site personnel**

  All site personnel were given advice on diseases associated with landfill such as tetanus, contamination due to contact with leachate, toxicity, asphyxia of landfill gas etc. Trainings on appropriate use of face mask, breathing apparatus, fire extinguisher, portable gas monitoring equipment and procedures for site monitoring of enclosed/ confined areas were specified.

The **EHS** system was reviewed continuously by the project management team during the implementation stage to improve its effectiveness.

4. IMPLEMENTING, MONITORING AND CONTROL OF EHS SYSTEM

Upon acceptance and approval of the environmental health and safety management system (**EHS**) by the project management team, it was incorporated into the construction work programme for the road at landfill site. The project management team then implemented, monitored and controlled the procedures for all stages of construction from foundation bored piling, installation of landfill capping, gas venting system to construction of reinforced concrete deck structure. Some of the procedures undertaken were illustrated in the following sections.

4.1 MEASURES TAKEN BEFORE COMMENCEMENT OF WORK

- **Tetanus inoculations to all site personnel**

  This was carried out to prevent infections to any open wounds due to possible exposure to the toxic waste material.

- **Engaging qualified Workplace Safety and Health Officer(WSHO) and Gas Assessor**

  Competent health and safety personnel, **WHSO** were engaged to implement the requirements in the environmental health and safety management system. In addition, competent Gas Assessor was engaged to monitor and measure various characteristics of landfill gas throughout the duration of excavation and boring works.

- **Training on use of safety equipment & respiratory mask**

  Site personnel were briefed and educated on all hazards associated with landfill. Trainings on correct use of respiratory mask to ensure right fitting and leak prevention were conducted (Figure 5).

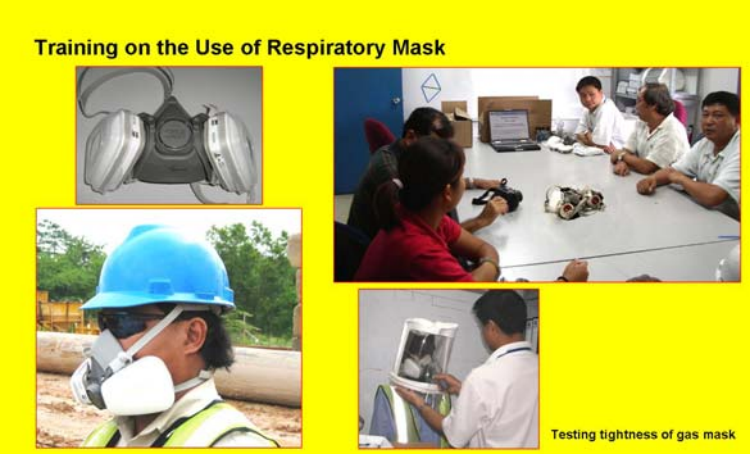

Figure 5: Training on safe use of respiratory mask

- **Put up warning signs at site**

  Various warning and prohibition signs in different languages were erected at strategic locations along the worksite before commencement of work. Work zone was also planned and demarcated to prevent unauthorised entry.

- **Emergency evacuation route**

  An emergency evacuation route and assembly point were identified together with other key contact persons and nearby medical facilities.

4.2 MEASURES TAKEN DURING WORK

- **Toolbox meeting/ site demonstration**

  Daily toolbox meeting was conducted by the WSHO prior to start of work at site. The work personnel would be instructed to comply with specific work method statement including health and safety measures to be taken.

- **Permit-to-Work system**

  The permit-to-work system was rigorously implemented for all construction activities. Every permit requested by the supervisors had to be approved by the project manager and it would be valid only for the day of application. The approved permit would be displayed prominently together with record of landfill gas measurement by Gas Assessor at the access point of barricaded work zone. The supervisors would be responsible to check the gas record hourly and control the access to work zone during excavation/ boring work.

- **Actions to be taken in the event of gas being detected during excavation / boring work**

  In the event that landfill gas measurements exceeded the threshold limits as shown in Figure 6, appropriate actions would be taken by the supervisors immediately.

Parameter	Measurement	Action required
Methane	>10% of Lower Explosive Limit (LEL)	Prohibit hot works Ventilate to restore methane to < 10% LEL (Figure 6.1)
	>20% LEL	Stop works Evacuate all working personnel / prohibit entry Ventilate to restore methane to < 10% LEL
Oxygen	<19%	Ventilate trench to restore oxygen to >19%
	<18%	Stop works Evacuate personnel / prohibit entry Increase ventilation to restore oxygen to >19%
Carbon Dioxide	>0.5%	Ventilate trench to restore carbon dioxide to <0.5%
	>1.5%	Stop works Evacuate personnel/ prohibit entry Ventilate to restore methane to <10% LEL and carbon dioxide to <0.5%

Figure 6: Actions in event of gas being detected

Figure 6.1 Landfill gas measurement and forced ventilation with air blower during bored piling work

- **Disposal of excavated waste material**

The excavated waste material was disposed at a nearby dumping site approved by NEA. The waste materials from the bored holes were transported to the designated dumping site immediately after excavation. A one metre thick backfill capping was then placed over the disposed waste to prevent contamination of surrounding area (see Figure 7). Cut off drains surrounding the dumping site was provided as part of the leachate control and recharge system.

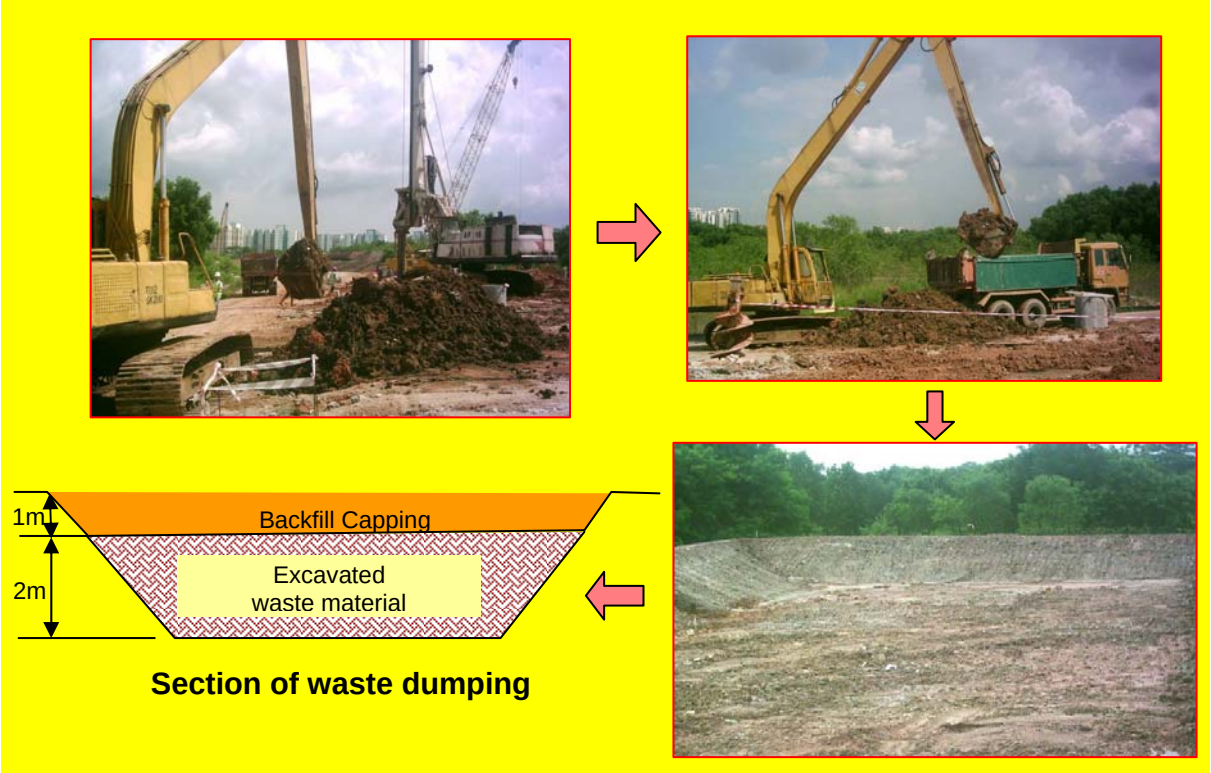

Figure 7: Excavated waste dumping scheme**.**

5. EVALUATION OF EFFECTIVENESS OF EHS SYSTEM

The EHS system implementation was most crucial for the foundation bored piling stage as deep excavation through the waste deposit layer was carried out. At the initial stage of work, progress was slow as the EHS procedures were carefully complied. Moreover, the landfill gas characteristics at different pile locations also varied unpredictably even with available data from monitoring wells.

The project management team then reviewed the work method statement and carried out pre-boring at random pile locations to determine their respective landfill gas concentration. Basing on the data collected, the entire road at landfill site was subdivided into a few zones. Boring work was then prioritized at zone with lower landfill gas concentration while the other zones with higher landfill gas concentration were ventilated to lower the various gas levels to below thresholds. These measures taken had been effective in controlling both EHS implementation and progress of work.

On the installation of landfill capping and gas venting system, the risk due to landfill related hazards was relatively lesser as the excavation work was kept within the original soil capping to landfill in an open air environment (Figures 8 & 9).

Layer of Geocomposite liner laid

Installation of Geotextile in progress

Figure 8 Installation of landfill capping system

Figure 9 Installation of landfill gas venting system

To ensure compliance with the EHS system by all site personnel, an independent qualified reviewer was engaged by the contractor to audit the site at half yearly interval. The audit had been useful as the reviewer also brought up site observations on behavior of work personnel to improve the procedures. Site personnel were guided to look out for potential hazards at each other work area.

On the whole, it was assessed that the EHS system implemented at site had been effective throughout the 3 years of construction of new road at landfill site. There was no incident due to landfill related hazards. The new road was successfully completed on schedule and opened to traffic on 24 Mar 09 (Figure 10).

Figure 10 Overview of completed new road at landfill site. Close up view shows gas venting outlet with control valve and flame arrestor in fenced enclosure at the road sidetable.

6. CONCLUSION

The project to build a new road on an existing landfill site at north eastern part of Singapore presented many challenges to the project team in terms of design, construction, monitoring and maintenance to avoid ill health and injuries for all associated work personnel. The successful completion of the new road on time, with good quality of work and zero incident associated with landfill related hazards attested to the effective application of risk management process by the project team.

The team had effectively established an environmental baseline to determine potential hazards, conducted risk analysis, determined mitigation measures, developed, implemented, monitored and controlled the work in accordance with the requirements in the environmental health and safety system (EHS).

Building road in landfill area is thus a viable option in optimizing land use in urbanized and land scarce Singapore to meet the demand of rapidly increasing road users.

7. REFERENCE

7.1 National Environment Agency (NEA), Landfill as-built drawings at Tampines Dumping Ground.